TECHNICAL NOTES

U.S. DEPARTMENT OF AGRICULTURE STATE OF COLORADO NATURAL RESOURCES CONSERVATION SERVICE

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To: All Offices

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Nutrient Management Planning Guidelines

This revised Agronomy Technical Note provides guidance for planners, producers, and consultants to develop nutrient management plans in accordance with the revised USDA Natural Resources Conservation Service (NRCS) Nutrient Management Policy, and NRCS Nutrient Management Conservation Practice Standard, Code 590.

General

Nutrient management is defined as managing the amount, source, placement, form, and timing of the application of nutrients and soil amendments to ensure adequate soil fertility for plant production while minimizing the potential for environmental degradation, particularly water quality impairment.

A nutrient management plan is a documented record of how nutrients will be used for plant production, prepared for reference and use by the producer or land owner.

A nutrient management plan may stand alone, or be an element of a more comprehensive conservation plan. When a nutrient management plan is part of a more comprehensive conservation plan, the provisions for nutrient management shall be compatible with other provisions of the plan.

Plans for nutrient management shall be approved initially and reviewed periodically by a "Certified" nutrient management specialist. The periodic review should coincide with the soil test cycle, not to exceed 5 years. The results of such reviews shall be documented in the plan, as well as the identification of the person who made the review. When a plan review indicates that a revision is needed, the revised plan shall also be approved by a certified nutrient management specialist.

Certification programs for nutrient management specialists that are currently acceptable in Colorado include: the American Society of Agronomy (ASA) Certified Crop Advisers Program; ASA American Registry of Certified Professionals in Agronomy, Crop, and Soil Science; and the National Association of Independent Crop Consultants Third Party Vendor Certification Program. An example signature page is provided in Exhibit E.

Plans for nutrient management shall be developed in compliance with all applicable Federal, State, and/or local regulations. Federal, State, and/or local regulations take precedence over USDA policy if they are more restrictive.

Nutrient Management Plans

Plans for nutrient management shall include the following components, as applicable.

1) **Site Aerial Photographs or Farm Maps, Including a Soils Map** - These maps are generally part of the overall conservation plan. Soil survey information is available at local USDA NRCS Field Offices.
2) **Current or Planned Plant Production Sequence or Crop Rotation –** A crop rotation is considered to be a planned sequence of crops growing in a regularly recurring succession on the same area of land, as contrasted to continuous culture of one crop, or growing a variable sequence of crops.
3) **Results of Pertinent Soil, Plant, Irrigation Water, Manure, or Other Organic By-Product Sample Analysis** – Nutrient budgets are to be based on current soil test analysis results and recommendations which are no older than 5 years. Other Federal, State, and/or local regulations may require soil sampling and/or manure analysis at more frequent intervals for some types of operations.
4) **Realistic Yield Goals for Crops Included in the Cropping Sequence or Crop Rotation** – A realistic yeild goal is a 5 year average for the field plus 5 percent for above average growing conditions.
5) **A Quantification of All Nutrient Sources** - Nutrient sources may include but are not limited to commercial fertilizers, animal manures and other organic by-products, irrigation water, atmospheric deposition, and legume credits.
6) **A Nutrient Budget for Nitrogen (N), Phosphorus (P), and Potassium (K) for the Current or Planned Plant Production Sequence or Crop Rotation -** A nutrient budget is needed to estimate the amount of nutrients available from all sources compared to the amount of nutrients required to meet crop requirements for the expected yield. When nutrient requirements exceed the amount of nutrients available, additional nutrients should be applied to meet crop requirements. Conversely, if nutrient supplies exceed crop requirements, management measures should be taken to ensure that excess nutrient inputs are decreased, or that their application will not cause detrimental effects to the crop, soil, or surrounding environment.
7) **Recommended Nutrient Application Rates, Timing, Form, and Methods of Application and Incorporation –** These specifications are to be provided to the producer for individual fields or for groups of fields depending on soil types, fertility status, yield goals, and the crop rotation.
8) **Location of Designated Sensitive Areas or Resources and Associated Nutrient Management Restrictions -** If present, sensitive resource areas and restrictions on nutrient applications shall be delineated on the aerial photographs or farm maps. This may include set backs required for application of animal manures, reduced application rates, soil conditions that require reduced application rates, restrictions on time of application, or areas with special resource concerns.
9) **Guidance for Implementation, Operation and Maintenance -** A number of items need to be reviewed on a regular basis. These include calibration of application equipment, maintaining a safe working environment, review and update of plan elements, periodic soil, water, plant, and organic amendment analysis, and monitoring.

Environmental Risk Assessment

An environmental risk assessment is required for sites located in hydrologic unit areas designated as having impaired water quality associated with nutrients. An environmental risk assessment is also required if manures or other organic by-products will be land applied. The Colorado Phosphorus Index or other risk assessment tools accepted by NRCS and Colorado State University (CSU) shall be used to make these assessments.

If a risk assessment is required, the nutrient management plan shall include a record of the site rating for each field, as well as information about conservation practices and management actions that can be applied to decrease the potential for nutrient movement from the field.

Nutrient Budget

An annual nutrient budget for N, P, and K is required for each field and crop in the production sequence or crop rotation. Nutrient budgets shall be based on current soil test results that are no older than 5 years. It is recommended, however, that soil tests be conducted annually for crops with high nutrient input requirements. Additionally, other Federal, State, and/or local regulations may require soil testing at more frequent intervals for some types of operations. Soil samples shall be collected and handled in accordance with CSU guidance.

There are two acceptable methods available for calculating a nutrient budget. The first is based on a soil test analysis and nutrient application recommendation as provided by CSU or other acceptable soil test laboratories. The second method is based on a balance between nutrients supplied to the field and the nutrients removed each year in the harvested crop. Both methods will need to be used to develop a nutrient budget unless soil tests are conducted annually.

Example Nutrient Budget Worksheets are provided in Exhibits A and B. Exhibit A may be used to develop nutrient budgets for years in the cropping sequence or rotation when soil test recommendations are available. Exhibit B may be used for years when soil test recommendations are <u>not</u> available. Equivalent worksheets are also acceptable provided they account for all nutrient sources.

Tables are provided in Exhibit C for estimating crop nutrient removal and nutrient credits for legumes, manures, and irrigation water. Example calculations are provided in Exhibit D.

Nutrient Budget Worksheet

This discussion follows the Nutrient Budget Worksheet provided in Exhibit B for years in the production sequence or crop rotation when soil test recommendations are <u>not</u> available.

A. Planned crop or crop rotation

Enter the planned crop on line A.

B. Yield goal

Enter the yield goal for the planned crop. A realistic yield goal is a 5 year average for the field plus 5% for exceptional growing conditions.

C. Nutrients removed by crop

Crop nutrient removal estimates are based on yield goals and the nutrient content of the harvested material. Average nutrient concentration values for most major crops grown in Colorado are listed in Table 1, Exhibit C. Local data may also be used if available.

C1. To estimate the average nutrient removal, enter the yield goal and harvest unit weight on line C1. Then multiply the yield by the harvest unit weight to calculate the pounds per acre of crop material removed.

C2. Refer to Table 1, Exhibit C, and determine the average nutrient concentrations of the harvested material. Enter the nutrient concentration values for N, P, and K on line C2.

C3. Multiply the pounds per acre weight from line C1 by the nutrient concentrations on line C2 and enter the product on Line C3.

C4. Convert the elemental P and K values from line C3 to fertilizer equivalent units on line C4, and enter on line F1.

D. Nitrogen Credits

D1. Legume credits from previous crop – Incorporation of forage legumes contributes N to the soil for the following crop. The N credit for incorporating alfalfa, red clover, birdsfoot trefoil, etc. is based on the percentage of legume left in the stand. To estimate the percentage of legume, count the number of crowns in one square foot of the field. Do this in several places and calculate an average (one plant may have several stems coming from the same crown). Use Table 2, Exhibit C, to estimate the percentage of legume remaining in the stand. The N credit for alfalfa is equal to the percentage of legume in the stand plus 40 lbs. N per acre. Enter the value on line D1.

Example: The average number of alfalfa plants per sq. ft. in a six year old stand is 4. From Table 2, Exhibit C, the percent of alfalfa in the stand would be about 65%. For this example the N credit would be: 65 + 40 = 105 lb N/ac

For forage legumes other than alfalfa such as clovers or trefoil, use 80% of the N credit for alfalfa.

For soybeans and dry beans, each bushel of yield to a maximum of 40 contributes about one pound of N to the soil for next crop. For example, a 30-bushel bean crop would contribute about 30 lbs. N per acre to the next crop, and a 60-bushel bean crop would contribute a maximum of about 40 lbs. N per acre.

D2. Residual N from previous manure applications - Organic N applied with manure is not 100% available to the crop in the year it is applied. Organic N must mineralize into inorganic forms before it can be used by the crop. Refer to Table 4, Exhibit C, to estimate the amount of N that will be available to the crop and enter the value on line D2.

D3. Irrigation water nitrate nitrogen - Irrigation water may contribute N to the crop in the form of nitrate (NO_3-N). This N is available for plant use when it is applied before crop flowering. To calculate the irrigation water NO_3-N credit, determine the concentration of NO_3-N in the irrigation water in parts per million (ppm) or milligrams per liter (mg l^{-1}). Then estimate the net amount of irrigation water (inches) to be applied before crop flowering. Multiply the net irrigation amount by the NO_3-N concentration (ppm or mg l^{-1}). Then multiply the product by a factor of .226 to convert to pounds per acre.

Example: It is estimated that a net application of 18 inches of irrigation water, with an NO_3-N concentration of 15 ppm will be applied to a corn crop prior to tasseling.

18 acre inches x 15 ppm x .226 = 61 lb NO_3-N/ac

D4. Other (e.g. atmospheric deposition, mulches, subsoil NO_3-N, crop residues) - Other N credits for sources such as atmospheric deposition, mulches, subsoil nitrates, soil organic matter, or other crop residues should be entered on line D4.

Atmospheric deposition information can be obtained from the National Atmospheric Deposition Program at http://nadp.sws.uiuc.edu. For the years 1994 through 1999 in Colorado, atmospheric N deposition averaged about 2 lbs. N per acre per year, with a range of about 0.5 to 3.5 pounds of N per acre per year.

The N contributions for mulches, crop residues, or other organic materials that are applied to the field can be estimated by multiplying the mass dry weight of the material applied times the corresponding N concentration.

In some instances, such as when high amounts of straw or corn stalks are incorporated into the soil, the N credit on line D4 may need to be a negative number to represent N immobilization. In this situation, an additional 30 lb. N per acre may be required to satisfy microbial biomass N requirements while the residues are decomposing.

D5. Total N credits - Add the N credits from lines D1 through D4 and enter the sum on line D5.

E. Sources of Nutrients Available to the Field

E1. Nitrogen credits - Enter the Total N credits from line D5 on line E1.

E2. Manure and organic material applied - Enter the estimated nutrient credits for manures or other organic by-products on line E2.

The application rates for nutrients applied with organic materials are derived from tons or gallons applied per acre and the corresponding nutrient content. The nutrient content of manure or other organic materials may be determined by laboratory analysis or estimated from acceptable book values. For examples of acceptable book values, see Table 3, Exhibit C.

To estimate the amount of N available to the crop from applied manure, refer to Table 4, Exhibit C.

For P, assume that 80% is plant available if manure has been applied to the field for 3 or more consecutive years. If manure has been applied to the field at less frequent intervals, assume that only 60% of the P applied is plant available.

E3. Starter fertilizer - If starter fertilizers will be applied, enter the amounts of nutrients to be applied on line E3.

E4. Other - Other nutrient additions, such as preplant fertilizer already applied or carry over nutrients from the previous year, may be entered on line E4.

E5. Total nutrient sources - Add the sources of nutrients available from lines E1 through E4, and enter the sum on line E5.

F. Nutrient balance

F1. Nutrients removed by harvested crop - Enter the estimated amount of crop nutrients required from line C4 on line F1.

F2. Nutrient balance - Subtract the nutrients removed by harvested crop (F1) from the amount of nutrient source (E5), and enter the difference on line F2.

If the balance on line F2 is a **positive** number, it represents the pounds of nutrients per acre that exceed crop requirements. In this situation, management changes may be needed to reallocate nutrient sources.

If the balance on line F2 is a **negative** number, it represents the pounds of additional nutrients needed per acre. In this situation, additional nutrients should be applied to meet crop requirements.

Exhibit A

Nutrient Budget Worksheet (based on a soil test recommendation)

Cooperator ____________________________________ Field__________ Crop year__________ Date__________

			N	P_2O_5	K_2O
A.	Planned crop	____________________			
B.	Yield goal	____________________			
C.	Soil test				
	C1.	Lab____________________ Date__________			
	C2.	Recommendation	______	______	______
D.	Nitrogen credits (lb/ac)		N		
	D1.	Legume credit from previous crop	______		
	D2.	Residual N from previous manure applications	______		
	D3.	Irrigation water nitrate nitrogen	______		
	D4.	Other (e.g. atmos. dep., subsoil NO_3-N)	______		
	D5.	Total N credits (D1 + D2 + D3 + D4)	______		
E.	Sources of nutrients available to the field (lb/ac)		N	P_2O_5	K_2O
	E1.	Nitrogen credits (D5)	______		
	E2.	Manure or other organic by-products	______	______	______
	E3.	Starter fertilizer	______	______	______
	E4.	Other	______	______	______
	E5.	Total nutrient sources	______	______	______
F.	Nutrient balance (lb/ac)				
	F1.	Soil test recommendation (C2)	______	______	______
	F2.	Nutrient balance (E5 minus F1)	______	______	______

If the balance on line F2 is a **positive** number, it represents the pounds of nutrients per acre that exceed crop requirements. In this situation, management changes may be needed to reallocate nutrient sources.

If the balance on line F2 is a **negative** number, it represents the pounds of additional nutrients needed per acre. In this situation, additional nutrients should be applied to meet crop requirements.

Source: Adapted from USDA, NRCS, Core4 Conservation Practices, Reference Material, 1999, Fig. 2-3.

Exhibit B

Nutrient Budget Worksheet (based on nutrients removed by harvested crops)

Cooperator ___________________________________ Field__________ Crop year__________ Date__________

A. Planned crop ____

B. Yield goal ____

C. Nutrients removed by planned crop

C1. Yield goal (units of measure) x Unit weight (lb) = pounds of crop material harvested

____________ x ____________ = ____________ lb/ac

C2. Nutrient content of harvested material (refer to Table 1, Exhibit C)

% N = ________ % P = ________ % K = ________

C3. Crop nutrient content (lb/ac)

N = [(C1)(C2/100)] = _____ P = [(C1)(C2/100)] = _____ K = [(C1)(C2/100)] = _____

C4. Convert to fertilizer equivalent units (lb/ac)

C3 N = _____N C3 P x 2.29 = _____P_2O_5 C3 K x 1.2 = _____K_2O

		N	P_2O_5	K_2O
D.	Nitrogen credits (lb/ac)	N		
D1.	Legume credit from previous crop	______		
D2.	Residual N from previous manure applications	______		
D3.	Irrigation water nitrate nitrogen	______		
D4.	Other (e.g. atmos. dep., subsoil NO_3-N)	______		
D5.	Total N credits (D1 + D2 + D3 + D4)	______		
E.	Sources of nutrients available to the field (lb/ac)	N	P_2O_5	K_2O
E1.	Nitrogen credits (D5)	______		
E2.	Manure or other organic by-products	______	______	______
E3.	Starter fertilizer	______	______	______
E4.	Other	______	______	______
E5.	Total nutrient sources	______	______	______
F.	Nutrient balance (lb/ac)			
F1.	Nutrients removed by harvested crop (C4)	______	______	______
F2.	Nutrient balance (E5 minus F1)	______	______	______

If the balance on line F2 is a **positive** number, it represents the pounds of nutrients per acre that exceed crop requirements. In this situation, management changes may be needed to reallocate nutrient sources.

If the balance on line F2 is a **negative** number, it represents the pounds of additional nutrients needed per acre. In this situation, additional nutrients should be applied to meet crop requirements.

Source: Adapted from USDA, NRCS, Core4 Conservation Practices, Reference Material, 1999, Fig. 2-3.

Exhibit C

Table 1. Average Crop Nutrient Concentrations

Crop	Typical yield per acre	Pounds per harvest unit	Harvest dry matter (%)	Average nutrient concentration (%) at harvest dry matter								
Grain Crops				**N**	**P**	**K**	**Ca**	**Mg**	**S**	**Cu**	**Mn**	**Zn**
Barley grain	110 bu	48	86	1.80	0.36	0.46	0.04	0.09	0.14	0.0014	0.0014	0.003
Barley straw	3 ton	2000	90	0.72	0.10	1.60	0.36	0.09	0.18	0.0005	0.014	0.002
Corn grain	160 bu	56	85	1.40	0.27	0.34	0.02	0.09	0.10	0.0006	0.0009	0.0015
Corn stover	4 ton	2000	90	1.00	0.18	1.35	0.26	0.20				
Oat grain	80 bu	32	86	1.90	0.32	0.42	0.07	0.10	0.17	0.001	0.004	0.0017
Oat straw	2 ton	2000	90	0.64	0.33	2.15	0.18	0.18	0.21	0.0007	0.003	0.006
Rye grain	30 bu	56	86	1.90	0.32	0.45	0.10	0.15	0.36	0.001	0.011	0.0015
Rye straw	1 ton	2000	90	0.45	0.11	0.62	0.24	0.063	0.09	0.027	0.004	0.002
Sorghum grain	60 bu	56	86	1.44	0.31	0.36	0.11	0.15	0.15	0.0003	0.001	0.001
Sorghum straw	3 ton	2000	90	0.97	0.14	1.20	0.43	0.27	0.12		0.01	
Sunflower seed	50 bu	25	90	2.88	0.56	1.00	0.16	0.30	0.15		0.002	
Sunflower stover	4 ton	2000	90	1.35	0.16	2.63	1.56	0.08	0.04		0.022	
Wheat HRW	40 bu	60	86	1.98	0.53	0.45	0.034	0.22	0.11	0.001	0.003	0.005
Wheat HRS	40 bu	60	86	2.24	0.53	0.45	0.034	0.22	0.11	0.001	0.003	0.005
Wheat SRW	40 bu	60	86	1.80	0.53	0.45	0.034	0.22	0.11	0.001	0.003	0.005
Wheat SWW	40 bu	60	86	1.55	0.53	0.45	0.034	0.22	0.11	0.001	0.003	0.005
Wheat SWS	40 bu	60	86	2.24	0.53	0.45	0.034	0.22	0.11	0.001	0.003	0.005
Wheat straw	1.5 ton	2000	90	0.60	0.06	1.05	0.18	0.09	0.15	0.0003	0.005	0.0015
Oil Crops				**N**	**P**	**K**	**Ca**	**Mg**	**S**	**Cu**	**Mn**	**Zn**
Canola seed	35 bu	50	90	3.5	.56	0.88						
Canola straw	3 ton	2000	90	0.5								
Flax seed	15 bu	56	93	3.5	0.51	0.76	0.20	0.39	0.23		0.005	
Flax straw	2 ton	2000	90	1.11	0.10	1.58	0.65	0.28	0.24			
Rape seed	35 bu	50	90	3.24	0.71	0.68		0.59				
Rape straw	3 ton	2000	90	4.00	0.39	3.00	1.32	0.05	0.61			
Soybean seed	35 bu	60	86	5.52	0.56	1.62	0.25	0.25	0.14	0.0014	0.0018	0.0014
Soybean stover	2 T.	2000	85	0.77	0.20	0.94	0.90	0.40	0.23	0.0009	0.01	0.003
Sunflower seed	1,100 lb	1	90	2.43	0.56	1.0	0.16	0.31	0.15		0.002	
Sunflower stover	4 ton	2000	90	1.35	0.16	2.63	1.56	0.08	0.04		0.021	
Silage crops				**N**	**P**	**K**	**Ca**	**Mg**	**S**	**Cu**	**Mn**	**Zn**
Alfalfa	10 ton	2000	25	0.85	0.08	0.68	0.24	0.08	0.05	0.0002	0.0008	
Corn	20 ton	2000	30	0.38	0.08	0.33	0.29	0.10	0.11	0.0003	0.0016	
Oat	10 ton	2000	25	0.53	0.07	0.47	0.08	0.06	0.05			
Sorghum	20 ton	2000	26	0.36	0.06	0.65						
Sorghum-sudan	10 ton	2000	23	0.35	0.09	0.52	0.10	0.08	0.009		0.001	

Adapted from: USDA, SCS, Agricultural waste management field handbook. 1992. Table 6-6; Meisinger, J.J, and G.W. Randall. 1991. Estimating nitrogen budgets for soil-crop systems. Table 5-4. *In* Follett, R.F., D.R. Keeney, and R.M. Cruse (ed.). Managing nitrogen for groundwater quality and farm profitability. SSSA, Madison, WI; and USDA, NRCS, plant nutrient content database. www.nhq.nrcs.usda.gov/BCS/nutri/tbb1.html, 2000.

Exhibit C

Table 1. Average Crop Nutrient Concentrations (continued)

Crop	Typical yield per acre	Pounds per harvest unit	Harvest dry matter (%)	Average nutrient concentration (%) at harvest dry matter								
Hay crops				**N**	**P**	**K**	**Ca**	**Mg**	**S**	**Cu**	**Mn**	**Zn**
Alfalfa	4 ton	2000	85	2.38	0.22	1.87	1.20	0.22	0.20	0.0006	0.005	0.005
Alsike clover	2 ton	2000	85	2.04	0.19	2.11						
Barley	2 ton	2000	85	1.20	0.22	1.27						
Big bluestem	3 ton	2000	80	0.88	0.68	1.40		0.16				
Birdsfoot trefoil	3 ton	2000	85	2.63	0.19	1.55	1.49	0.34				
Bluegrass	2 ton	2000	85	1.49	0.18	1.47						
Crested wheatgrass	1 ton	2000	85	1.20	0.23	2.28	0.31	0.20	0.09			
Indiangrass	3 ton	2000	85	0.85	0.72	1.02	0.13					
Lespedeza	3 ton	2000	85	1.98	0.18	0.90	0.95	0.18	0.28		0.013	
Little bluestem	3 ton	2000	80	0.88	0.68	1.16		0.16				
Oat	2 ton	2000	85	1.51	0.20	1.34						
Orchardgrass	6 ton	2000	85	1.45	0.22	2.24	0.25	0.20	0.22	0.001	0.007	
Red clover	2 ton	2000	85	2.25	0.22	1.60	1.17	0.30	0.12	0.0007	0.009	0.006
Reed canarygrass	6 ton	2000	85	1.45	0.24	2.54	0.31					
Ryegrass	5 ton	2000	85	1.45	0.25	1.86	0.55	0.30				
Smooth bromegrass	5 ton	2000	85	1.59	0.18	2.16	0.40	0.16	0.16			
Sweetclover	2 ton	2000	85	2.22	0.23	1.40						
Switchgrass	3 ton	2000	85	0.98	0.09	1.62	0.24	0.21				
Tall fescue	3 ton	2000	85	1.67	0.17	1.70	0.26	0.16				
Timothy	2 ton	2000	85	1.00	0.19	1.38	0.30	0.10	0.09	0.0005	0.005	0.003
Sugar crops				**N**	**P**	**K**	**Ca**	**Mg**	**S**	**Cu**	**Mn**	**Zn**
Sugar beets	20 ton	2000	23	0.25	0.08	0.28	0.11	0.08	0.03	0.0001	0.0025	
tops			18	0.45	0.04	1.03	0.18	0.19	0.10	0.0002	0.0010	
Fruit crops				**N**	**P**	**K**	**Ca**	**Mg**	**S**	**Cu**	**Mn**	**Zn**
Apples	500 bu	48	18	0.08	0.02	0.16	0.03	0.02	0.04	0.0001	0.0001	0.0001
Cantaloupe	180 cwt	100	10	0.17	0.09	0.46		0.34				
Grapes	12 ton	2000	20	0.14	0.10	0.50		0.04				
Peaches	15 ton	2000	12	0.14	0.03	0.19	0.01	0.03	0.01			0.0010
Tomatoes	22 ton	2000	6	0.19	0.04	0.33	0.02	0.03	0.04	0.0002	0.0003	0.0001

Adapted from: USDA, SCS, Agricultural waste management field handbook. 1992. Table 6-6; Meisinger, J.J, and G.W. Randall. 1991. Estimating nitrogen budgets for soil-crop systems. Table 5-4. *In* Follett, R.F., D.R. Keeney, and R.M. Cruse (ed.). Managing nitrogen for groundwater quality and farm profitability. SSSA, Madison, WI; and USDA, NRCS, plant nutrient content database. www.nhq.nrcs.usda.gov/BCS/nutri/tbb1.html, 2000.

Exhibit C

Table 1. Average Crop Nutrient Concentrations (continued)

Crop	Typical yield per acre	Pounds per harvest unit	Harvest dry matter (%)	Average nutrient concentration (%) at harvest dry matter								
Vegetable Crops				**N**	**P**	**K**	**Ca**	**Mg**	**S**	**Cu**	**Mn**	**Zn**
Bell peppers	9 ton	2000	8	0.20	0.12	0.49		0.04				
Beans, dry	25 bu	60	90	3.60	0.45	0.86	0.08	0.08	0.21	0.0008	0.0013	0.0025
Cabbage	360 cwt	100	9	0.33	0.04	0.27	0.05	0.02	0.11	0.0001	0.0003	0.0002
Carrots	350 cwt	100	12	0.19	0.04	0.25	0.05	0.02	0.02	0.0001	0.0004	
Celery	27 ton	2000	8	0.17	0.09	0.45						
Cucumbers	8 ton	2000	5	0.20	0.07	0.33		0.02				
Lettuce (heads)	340 cwt	100	5	0.23	0.08	0.46						
Onions	370 cwt	100	10	0.30	0.06	0.22	0.07	0.01	0.12	0.0002	0.0050	0.0021
Peas	1.5 ton	2000	20	0.84	0.40	0.90	0.08	0.24	0.24			
Potatoes	290 cwt	100	25	0.40	0.06	0.52	0.01	0.03	0.03	0.0002	0.0004	0.0002
Snap beans	3 ton	2000	13	0.39	0.26	0.96	0.05	0.10	0.11	0.0005	0.0009	
Spinach	80 cwt	100	9	0.42	0.05	0.56	0.10					
Sweet corn	160 cwt	100	27	0.43	0.24	0.58		0.07	0.06			
Sweet potatoes	7 ton	2000	28	0.30	0.04	0.42	0.03	0.06	0.04	0.0002	0.0004	0.0002
Table beets	15 ton	2000	13	0.26	0.08	0.28	0.03	0.02	0.02	0.0001	0.0007	
Wetland plants				**N**	**P**	**K**	**Ca**	**Mg**	**S**	**Cu**	**Mn**	**Zn**
Cattails	8 ton	2000		1.02	0.18							
Rushes	1 ton	2000		1.67								
Saltgrass	1 ton	2000		1.44	0.27	0.62						
Sedges	0.8 ton	2000		1.79	0.26		0.66					
Water hyacinth					3.65	0.87	3.12					
Duckweed				3.36	1.00	2.13						
Arrowweed				2.74								
Phragmites				1.83	0.10	0.52						

Adapted from: USDA, SCS, Agricultural waste management field handbook. 1992. Table 6-6; Meisinger, J.J, and G.W. Randall. 1991. Estimating nitrogen budgets for soil-crop systems. Table 5-4. *In* Follett, R.F., D.R. Keeney, and R.M. Cruse (ed.). Managing nitrogen for groundwater quality and farm profitability. SSSA, Madison, WI; and USDA, NRCS, plant nutrient content database. www.nhq.nrcs.usda.gov/BCS/nutri/tbb1.html, 2000.

Exhibit C

Table 2. Forage Legume Nitrogen Credits

Number of plants per sq. ft.	New seeding	1st year hay	2nd year hay	3rd year hay and older
	% Legume in stand			
20	100			
18	90			
16	80	100		
14	70	85		
12	60	70		
10	50	60	100	
8	40	50	80	
6	30	35	60	100
4	20	25	40	65
2	10	10	20	30
0	0	0	0	0

Source: Tesar, M.B., and V.L. Marble, 1988, Alfalfa establishment, in Alfalfa and alfalfa improvement, Agron. Monograph 29, p.304, Amer.Soc.Agron., Madison, WI.

Table 3. Approximate nutrient composition of various types of animal manure at time of application.*

Type of manure	Moisture content %	Total N	NH_4-N [a]	P_2O_5	K_2O
Solid handling systems		**Pounds per ton**			
Swine	82	10	6	9	8
Beef	32	23	7	24	41
Dairy Cattle	46	13	5	16	34
Sheep	31	29	5	26	38
Chickens without litter	55	33	26	48	34
with litter	25	56	36	45	34
Turkeys without litter	78	27	17	20	17
with litter	71	20	13	16	13
Horses without bedding	22	19	4	14	36
Liquid handling systems [b]		**Pounds per 1000 gallons**			
Swine liquid pit	96	36	26	27	22
single-stage anaerobic	99	7	6	2	7
two-stage anaerobic	99	4	3	2	7
Beef lagoon [c]	99	4	2	9	5
Dairy Cattle liquid pit	92	24	12	18	29
lagoon c	99	4	2	4	10
Poultry liquid pit	87	80	64	36	96

Source: CSU Cooperative Extension Bulletin 568A, Best Management Practices For Manure Utilization, Table 4, 1999.

[a] Ammonia fraction can vary significantly across time and systems. Numbers given are for planning purposes only. Manure analysis is needed to accurately determine the ammonia fraction.

[b] Application conversion factor: pounds per 1000 gallons x 27.15 = pounds per acre-inch.

[c] Includes runoff water.

* These values are derived from the USDA Agricultural Waste Management Field Handbook, 1992, and are modified with data collected from Colorado feeding operations when possible. Nutrient composition of manure will vary with age, breed, feed rations, and manure handling.

Exhibit C

Table 4. Approximate percent of organic N mineralized from various manure sources over three years.

Manure source	% N available		
	1st year	2^{nd} year	3rd year
Beef and dairy cattle			
solid (without bedding)	30-40	10-15	5-10
liquid (anaerobic)	25-35	5-10	2-7
Swine			
solid	45-55	3-8	2-7
liquid (anaerobic)	35-45	4-9	2-7
Sheep			
Solid	20-30	10-15	5-10
Horse			
solid (with bedding)	15-25	5-10	2-7
Poultry			
solid (without litter)	30-40	10-15	5-10

Source: Best Management Practices for Manure Utilization, CSU Cooperative Extension Bulletin 568A, 1999.

Exhibit D

Nutrient Budget Example

Rotation:	sugar beet	silage corn	dry beans	malt barley
Yield goals:	23 tons	30 tons	50 bu	100 bu
Manure:	20 tons beef manure fall applied and incorporated after sugar beets			
Irrigation N:	15 ppm NO_3-N			

Year 1 - see Exhibit A

A. sugar beet
B. 23 tons
C1. Colorado State University
C2 N = 100 lb/ac P_2O_5 = 75 lb/ac K_2O = 0 lb/ac
D1. 0
D2. 0
D3. 18 in x 15 ppm x .226 = 61 lb N/ac
D4. 2 lb N/ac (atmospheric deposition)
D5. 61 + 2 = 63 lb N/ac

		N	P_2O_5	K_2O
E.	Sources of nutrients available to the field (lb/ac)			
E1.	Manure or other organic by-product applied			
E2.	Nitrogen credits (D5)	63		
E3.	Starter fertilizer			
E4.	Other			
E5.	Total nutrient sources	63		
F1.	Soil test recommendation (C2)	100	75	
F2.	Nutrient balance (E5 – F1)	-37	-75	

Year 2 – see Exhibit B

A. silage corn
B. 30 ton
C1. 30 ton/ac x 2000 lb/ton = 60,000 lb/ac
C2. %N = 0.38 %P = 0.08 %K =0.33
C3. N = 60,000 x 0.0038 = 228 P = 60,000 x 0.0008 = 48 K = 60,000 x 0.0033 = 198
C4. N = 228 lb/ac P_2O_5 = 48 x 2.29 = 110 lb/ac K_2O = 198 x 1.2 = 238 lb/ac
D1. 0
D2. 0
D3. 18 in (applied before tasseling) x 15 ppm x .226 = 61 lb N/ac
D4. 2 lb N/ac (atmospheric deposition)
D5. 61 + 2 = 63 lb N/ac

		N	P_2O_5	K_2O
E.	Sources of nutrients available to the field (lb/ac)			
E1.	Manure or other organic by-product applied	184	288	820
E2.	Nitrogen credits (D5)	63		
E3.	Starter fertilizer			
E4.	Other			
E5.	Total nutrient sources	247	288	820
F 1.	Nutrients removed by harvested crop (C 4)	228	110	238
F 2.	Nutrient balance (E5 – F1)	19	178	582

Exhibit D

Nutrient Budget Example (continued)

Year 3 – see Exhibit B

A.	dry beans			
B.	30 bu			
C1.	30 bu/ac x 60 lb/bu = 1800 lb/ac			
C2.	%N = 3.60 %P = 0.45 %K = 0.86			
C3.	N = 1,800 x 0.036 = 65 P = 1,800 x .0045 = 8	K = 1,800 x .0086 = 15		
C4.	N = 65 lb/ac P_2O_5 = 8 x 2.29 = 18 lb/ac	K_2O = 15 x 1.2 = 18 lb/ac		
D1.	0			
D2.	20 ton x 23 lb N/ton x 15% = 69 lb N/ac			
D3.	12 in (applied before flowering) x 15 ppm x .226 = 41 lb N/ac			
D4.	2 lb N/ac (atmospheric deposition)			
D5.	69 + 41 + 2 = 112 lb N/ac			
E.	Sources of nutrients available to the field (lb/ac)	N	P_2O_5	K_2O
E 1.	Manure or other organic by-product applied	___	___	___
E 2.	Nitrogen credits (D5)	112	___	___
E 3.	Starter fertilizer	___	___	___
E 4.	Other	19	178	582
E 5.	Total nutrient sources	131	178	582
F 1.	Nutrients removed by harvested crop (C4)	65	18	18
F 2.	Nutrient balance (E5 – F1)	66	160	564

Year 4 – see Exhibit B

A.	malt barley			
B.	100 bu			
C1.	100 bu x 48 lb/bu = 4800 lb crop material removed			
C2.	% N = 1.80 % P = 0.36 % K = 0.46			
C3.	N = 4,800 x 0.018 = 86 P = 4,800 x .0036 = 17	K = 4,800 x .0046 = 22		
C4.	N = 86 lb/ac P_2O_5 = 17 x 2.29 = 39 lb/ac	K_2O = 22 x 1.2 = 26 lb/ac		
D1.	30 lb N/ac			
D2.	20 tons x 23 lb N/ton x 10% = 46 lb N/ac			
D3.	12 in (applied before flowering) x 15 ppm x .226 = 41 lb N/ac			
D4.	2 lb N/ac (atmospheric deposition)			
D5.	30 + 46 + 41 + 2 = 119 lb N/ac			
E.	Sources of nutrients available to the field (lbs. per acre)	N	P_2O_5	K_2O
E1.	Manure or other organic by-product applied	___	___	___
E2.	Nitrogen credits (D5)	119	___	___
E3.	Starter fertilizer	___	___	___
E4.	Other	66	160	564
E5.	Total nutrient sources	185	160	564
F1.	Nutrients removed by harvested crop (C4)	86	39	26
F2.	Nutrient balance (E5 – F1)	99	121	538

Exhibit E

The attached Nutrient Management Plan has been prepared for :

____

Planner ____________________________________ Date _____________

Approved by ____________________________________ Date _____________

Certification No. ___________________________ Expiration Date _____________

Reviewed by ____________________________________ Date _____________

Certification No. ___________________________ Expiration Date _____________

Reviewed by ____________________________________ Date _____________

Certification No. ___________________________ Expiration Date _____________

Reviewed by ____________________________________ Date _____________

Certification No. ___________________________ Expiration Date _____________

Reviewed by ____________________________________ Date _____________

Certification No. ___________________________ Expiration Date _____________